The rest of the diagram represents the forces which we found when the disks were at distances of 10 and 5 millims. asunder. The forces which presented themselves at these distances are to be attributed mainly to a true Crookes's reaction between the disks; and they seem to warrant the conclusion that Crookes's reaction was manifested at a distance of at least 10 millims. in a hydrogen vacuum, when the outstanding tension was as much as 5 millims. of mercury.

At distances of from 20 to 80 millims. the very feeble force acting on the glass disk in our apparatus seemed to vary about inversely as the tension. As already mentioned, it appeared to be nearly independent of the distance when the distance exceeded 20 millims.

At distances of 5, 10, and 20 millims. the force on the swinging disk made some approach to varying at each tension inversely as the distance. But, so far as may be judged from our measures of such exceedingly feeble forces, there is a sensible deviation from this law at most of the tensions.

Moreover the diagram, taken as a whole, seems to suggest, in conformity with the dynamical theory, that the law changes with variations of density. For if the law were the same at all the observed tensions, the converging lines in the diagram should converge to points in the axis of abscissas, whereas they converge towards points lower down.

We will postpone the further discussion of the observations already made with this apparatus until we can supplement them by others.

## II. "On the Structure of *Magelona*." By W. C. M'Intosh, M.D., F.R.S.E., F.L.S. Communicated by G. Busk, F.R.S., V.P.L.S. and Z.S. Received January 23, 1877.

(Abstract.)

This annelid was first discriminated* by Dr. George Johnston, of Berwick; but as his description (under the name *Mœa mirabilis*) was not published till 1865, the above-mentioned title, given to the same type, from the Island of St. Catherine, off the coast of Brazil, by Dr. Fritz Müller, has the priority. It is a comparatively small form, its slender body being divided into two well-marked regions; while anteriorly two long papillose tentacles are attached to the base of a remarkable spathulate, eyeless snout, which it dextrously uses to perforate sand near low-water mark at St. Andrews and other sandy shores on both east and west coasts.

The structure may be examined under the following heads:—

*Cuticle.*—This chitinous transparent layer is densest on the snout and anterior region of the body, both being much exposed in the boring-operations. Throughout the rest of the body it attains its maximum thickness over the nerve-cords in the ventral median line. No cilia occur

* From specimens procured by the distinguished botanist, Dr. Greville.

anywhere on its surface, and only faint indications of pores exist in certain regions. Fine motionless palpocils abound all over the cuticle.

The *Hypoderm* forms a very large proportion of the tissues of the flattened snout, the whole region outside the four muscular compartments being occupied by it; so that, in transverse section, it assumes on each side the shape of a long lanceolate process, which much resembles a leaf with its midrib and veins. Throughout the anterior and posterior regions of the body it forms a complete sheath, with various thickenings, and at the tip of the tail ends in two lateral styles, the glandular tissue of which (as in the dorsal and ventral processes) is arranged in a very regular manner. In minute structure the hypoderm much resembles the Nemertian cutis, presenting under pressure in the fresh animal a series of flask-shaped glands or cells, from which the contents escape as clear or granular globules. Moreover, it contains a vast number of bacillary cells, some of which have pigment and a large clear globule. In the hypoderm lie the nervous system and neural canals.

*Muscular System.*—The four longitudinal muscles of the spathulate snout are arranged within a curious framework of chitinous basement-tissue, which in section assumes various shapes—in front being like a pair of spectacles, then a figure of eight, and for a considerable distance very much resembling a crown. This framework exercises an important influence on the functions of the part. The central pair of muscles are confined to the snout; the lateral pass behind the mouth to constitute the ventral longitudinal pair. In the preoral chamber are a strong transverse muscle (acting as the chief approximator of the sides) and a vertical muscle. The muscles of the body-wall (besides the pair mentioned) are circular, longitudinal dorsal, vertical, oblique, external or lateral vertical and transverse ventral. Anteriorly all are powerfully developed for the peculiar functions of the region, viz. the compression of the blood-channels and the thrusting out of the proboscis. The muscles of the ninth body-segment are modified so as to form great constrictors, which have a slightly spiral arrangement. In addition to those of the body-wall, anteriorly, are the long and short retractor muscles of the proboscis, and various bands acting on the buccal and pharyngeal regions. In the posterior division of the body the transverse ventral muscles become atrophied; but the dorsal and ventral longitudinal muscles, though constricted at the ninth segment, extend throughout; and the other muscles of the body-wall are likewise present.

*Digestive System.*—A **T**-shaped slit leads into the buccal region, then follow pharynx, œsophagus, ventricular division, and intestine; while to the junction of the first and second is attached the proboscis. The pharyngeal division is furnished with complex muscular layers and convoluted internal surface, and it is thrust into the base of the proboscis in full expulsion. It is probably the homologue of the *proventriculus* in such Annelids as the Syllidæ. The proboscis, again, is an instance of the separa-

tion and modification of a part of the digestive canal to aid in the ceaseless perforations in the sand. Its internal surface is covered by a thick, transparent chitinous layer, devoid of pores. The relaxation of its own retractors, and the contraction of the muscular anterior region of the body, cause it to yield readily to a powerful stream of blood sent from behind; and it smoothly unrolls from the margin of the lower lip like a very supple membrane. This extrusion goes on until the brownish mass of the pharyngeal region approaches the front of the first body-segment, when its muscular coil slips into the base of the proboscis, like a plug, assisting to retain the blood therein, and giving firmness to the whole organ. Thus, in its progress forward, the flattened snout of the annelid is thrust amongst the fine sand which it haunts (with an undulating and insinuating motion) till it has advanced about its own length; then the proboscis is ejected to its full extent like an india-rubber dilator, so as to make a suitable channel for the occupation of the body, while again pressing onward the exploratory snout. All the retractile arrangements are next brought into play; the fan-shaped vertical muscular fibres pull in the last extruded region, the short and long retractors act on the entire organ, and the withdrawal of the pharyngeal protrusion makes an open channel for the backward stream of blood, which rushes into the vessels of the anterior region of the body out of the returning organ, further constricted by its own circular muscular coat. There is no differentiation between the succeeding œsophageal and ventricular regions, the glandular internal tunic in each being alike. The latter ceases, after a marked constriction, at the beginning of the tenth body-segment; and thereafter the intestine, which has much more lax glandular tissue and abundant fatty globules, proceeds to the dorsal anus near the tip of the tail. The walls of this region are richly furnished with capillaries; and cilia are very evident on the internal surface near the tail.

*Circulatory System.*—An interesting feature is the fact that the blood is a densely corpusculated fluid, the corpuscles having a pinkish colour. There are two large dorsal vessels which arise, near the tip of the tail, from the bifurcation of the ventral trunk. They pass forward along the dorsal arch of the alimentary canal, receiving in each segment a large branch from the ventral trunk and numerous capillaries from the intestinal wall, until the posterior border of the tenth segment is reached. At this part their dilated walls are supplied with powerful muscles, which, on the relaxation of the great muscles of the ninth segment, enable them to perform the functions of contractile chambers or "hearts," and by vigorous systole send the blood forward in a swift stream along the single dorsal vessel of the anterior region. On arriving at the base of the snout the vessel ends in the efferent branch to the tentacle on each side. The current rushes along the latter (nearly at right angles to the dorsal trunk) to the tips, sending off in each a web of circumferential capillaries throughout the greater part of its length, and terminating in the afferent

vessel, which proceeds backward, collecting, as it goes, the capillary streams, and then ends by turning forward at the base of the snout as the efferent cephalic vessel. The latter has no evident capillaries, but bends round at the tip of the flattened organ to terminate in the afferent cephalic vessel. A curious change takes place in the majority of those *Mageloncæ* which are provided with the convoluted lateral organs of the body, mentioned further on, in autumn. The cephalic vessels are much abbreviated, and the direction of the current at the base of the snout is somewhat modified. The blood from the head and anterior region collects into a series of large vascular meshes which occur in the anterior region of the body, and in which the current is for the most part under the control of the greatly developed muscles of the body-wall. Thus it happens, as formerly indicated, that the contraction of the latter, and of the special muscular apparatus which closes the communication with the posterior region at the ninth segment, drives the blood forward to unroll the proboscis. This muscular arrangement in the anterior region and the muscular walls of the vessels themselves at the posterior part of the same division of the body send the current through the relaxed barrier at the ninth segment into the muscular ventral blood-vessel of the posterior region, and onward to the tail, where the trunk ends by bifurcating into the two dorsal vessels. In each segment a lateral branch leaves the ventral trunk at the anterior dissepiment, turns round and proceeds backward to the next dissepiment, and terminates in the branch to the dorsal vessel. Further, as first observed by Dr. Fritz Müller, a sac-like dilatation takes place shortly after the commencement of the latter, and it fills at intervals, the distention being followed by a contraction which sends the blood onward by the branch to the dorsal vessel.

In vigorous specimens, the currents of the blood are as swift and beautiful as in the tails of young salmon and other translucent vertebrates. When examined in the *liquor sanguinis* of the living animal (as in a favourable view of a healthy tentacle) the blood-corpuscles show a pale nucleus.

*Nervous System.*—The central mass of the nervous system lies in front of the preoral chamber in the fork of the median muscles, and consists of the ordinary ganglion-cells with connective-tissue bands. No eyes or other sense-organs exist, though the animal is extremely sensitive to light and other stimuli, and lives in regions where there is abundance of sunshine. Two main nerve-trunks proceed backward in the hypoderm—at first outside, then under, and finally to the inner border of the ventral longitudinal muscles. At the commencement each is accompanied by a neural canal (the " tubular fibre " of the late M. Claparède); but, before leaving the anterior region of the body, the canals glide inward and coalesce into a single large median one. The whole central nervous system is hypodermic.

So far as present examination goes, the Annelida present four con-

spicuous modifications in regard to the position of the great nerve-trunks :—

(1) Some have the trunks situated within the muscular layers, or in a central hiatus between the ventral longitudinal muscles, the transverse band between the latter as well as the hypoderm being external.

(2) The cords (as in *Magelona*) are distinctly hypodermic in position, the oblique muscles of the body-wall being attached to a transverse band above them, or to the summit or sides of the area containing them.

(3) The trunks may be embraced by the closely approximated (almost connate) ventral or other longitudinal muscles which overlap the nerve-area.

(4) This group is formed by those in which the cords are separate throughout, being

(*a*) in the substance of the ventral longitudinal muscles,
or (*b*) below or at the edge of the same muscles and within the circular coat.

The neural canals, as far as examined, occur in about thirteen families.

*Tentacles.*—These remarkable organs extend to about two inches, but are capable of even greater elongation. They are composed of cuticle, hypoderm, basement-tissue, circular and longitudinal muscular coats, the latter having a raphe at each pole in transverse section. Each forms a hollow contractile process furnished with a series of large cylindrical papillæ along the anterior border, a series of central longitudinal muscular fibres giving the latter appendages a sucker-action. The afferent vessel is attached to the raphe next the papillæ, the efferent to the raphe at the smooth border. The entire organ is reproduced with considerable rapidity.

*Reproductive Organs.*—The ova and spermatozoa are present in each sex in great abundance in the posterior region of the body, and attain perfection in summer and autumn. On the sides of the body, also, peculiar convoluted organs occur in processes composed of the cuticle, hypoderm, and basement-tissue.

The systematic position of *Magelona*, with its peculiar external form and internal structure, was a source of uncertainty to Dr. George Johnston, the only author who attempted its consideration in this respect. So puzzled was he that he placed it (as *Mœa mirabilis*) at the end of his Catalogue for the British Museum, under a family specially constituted for itself (viz. Mæadæ). In the Catalogue of the Fauna of St. Andrews it was located between the Chætopteridæ and the Spionidæ ; but the results of further investigation clearly relegate it to the latter group*. It leans, indeed, wholly to the Spionidæ in minute structure, and especially to such forms as *Prionospio* and *Heterospio* ; though it is true that in the marked regional distinctions, and the great length of the posterior division of the

* Proc. Roy. Soc. Edinb. 1875–76, vol. ix. no. 94, p. 123.

body, it approaches *Spiochætopterus.* While it conforms to the Spionidæ in the structure of its body-wall and bristles, it differs in regard to the absence of the dorsal branchiæ; and further, the short, pinnate and ciliated anterior branchial organs of *Prionospio* appear to be the nearest approach to its elongated tentacles. In the mechanism of its proboscis and in the structure of its snout and circulatory organs, again, it presents features *sui generis.*

## III. "On a new Form of Tangential Equation." By John Casey, LL.D., F.R.S., Professor of Higher Mathematics in the Catholic University of Ireland. Received January 24, 1877.

(Abstract.)

If a variable line make an intercept $\nu$ on the axis of $x$, and an angle $\phi$ with it on the negative side, the equation of this line will be

$$x+y\cot\phi-\nu=0.$$

The quantities $\nu$ and $\phi$ will determine the position of the line, and may therefore be called its coordinates; hence any relation between $\nu$ and $\phi$, such as $\nu=f(\phi)$, will be the tangential equation of a curve which is the envelope of the line.

The equation $\nu=f(\phi)$ forms the subject of this paper. It is remarkable for the facility with which it can be transformed into the ordinary Cartesian and tangential equation, as well as into the polar and intrinsic equation of a curve. In a great variety of cases it gives, in a simple form, results which, by other methods, are very cumbersome or nearly impracticable. I have illustrated it throughout by numerous examples, many of which are of historical interest.

The following is an outline of the contents of the paper:—

Chapter I. shows how to transform Cartesian and polar equations into the form $\nu=f(\phi)$. In the course of the investigation a remarkable system of curves of the *nth* class, which are concomitants to any curve of the *nth* degree, are introduced, and their leading properties investigated.

Chapters II., III. are occupied with the transformation of the intrinsic equation, and *vice versâ*, and some allied subjects. In these chapters the whole theory of evolutes, involutes, curvature, &c. are fully considered.

Chapters IV., V. are devoted to the investigation of the properties of cycloids and hypocycloids by their tangential equations. A large number of new properties of these curves are given. The following may be taken as specimens:—1st. If three tangents to a cycloid be given, the envelope of the tangent at its vertex is a parabola. 2nd. If two tangents to a cycloid contain a given angle, the locus of the centre of the circle described about the triangle formed by the two tangents and their chord of contact is a right line.

Chapter VI. contains the theory of positive and negative pedals. The